SHIP PRODUCTION COMMITTEE
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EDUCATION AND TRAINING

September 1989
NSRP 0310

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

1989 Ship Production Symposium

Paper No. 17: Significantly Reduced Shipbuilding Costs Through Constraint(s) Management

U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION,
NAVAL SURFACE WARFARE CENTER

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<tr><td colspan="4">Report Documentation Page</td><td colspan="2">Form Approved
OMB No. 0704-0188</td></tr>
<tr><td colspan="6">Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.</td></tr>
<tr><td colspan="2">1. REPORT DATE
SEP 1989</td><td colspan="2">2. REPORT TYPE
N/A</td><td colspan="2">3. DATES COVERED
-</td></tr>
<tr><td colspan="4" rowspan="3">4. TITLE AND SUBTITLE
The National Shipbuilding Research Program 1989 Ship Production Symposium Paper No. 17: Significantly Reduced Shipbuilding Costs Through Constraint(s) Management</td><td colspan="2">5a. CONTRACT NUMBER</td></tr>
<tr><td colspan="2">5b. GRANT NUMBER</td></tr>
<tr><td colspan="2">5c. PROGRAM ELEMENT NUMBER</td></tr>
<tr><td colspan="4" rowspan="3">6. AUTHOR(S)</td><td colspan="2">5d. PROJECT NUMBER</td></tr>
<tr><td colspan="2">5e. TASK NUMBER</td></tr>
<tr><td colspan="2">5f. WORK UNIT NUMBER</td></tr>
<tr><td colspan="4">7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Surface Warfare Center CD Code 2230 - Design Integration Tools Bldg 192 Room 128 9500 MacArthur Blvd Bethesda, MD 20817-5700</td><td colspan="2">8. PERFORMING ORGANIZATION REPORT NUMBER</td></tr>
<tr><td colspan="4" rowspan="2">9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)</td><td colspan="2">10. SPONSOR/MONITOR’S ACRONYM(S)</td></tr>
<tr><td colspan="2">11. SPONSOR/MONITOR’S REPORT NUMBER(S)</td></tr>
<tr><td colspan="6">12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited</td></tr>
<tr><td colspan="6">13. SUPPLEMENTARY NOTES</td></tr>
<tr><td colspan="6">14. ABSTRACT</td></tr>
<tr><td colspan="6">15. SUBJECT TERMS</td></tr>
<tr><td colspan="3">16. SECURITY CLASSIFICATION OF:</td><td rowspan="2">17. LIMITATION OF ABSTRACT
SAR</td><td rowspan="2">18. NUMBER OF PAGES
21</td><td rowspan="2">19a. NAME OF RESPONSIBLE PERSON</td></tr>
<tr><td>a. REPORT
unclassified</td><td>b. ABSTRACT
unclassified</td><td>c. THIS PAGE
unclassified</td></tr>
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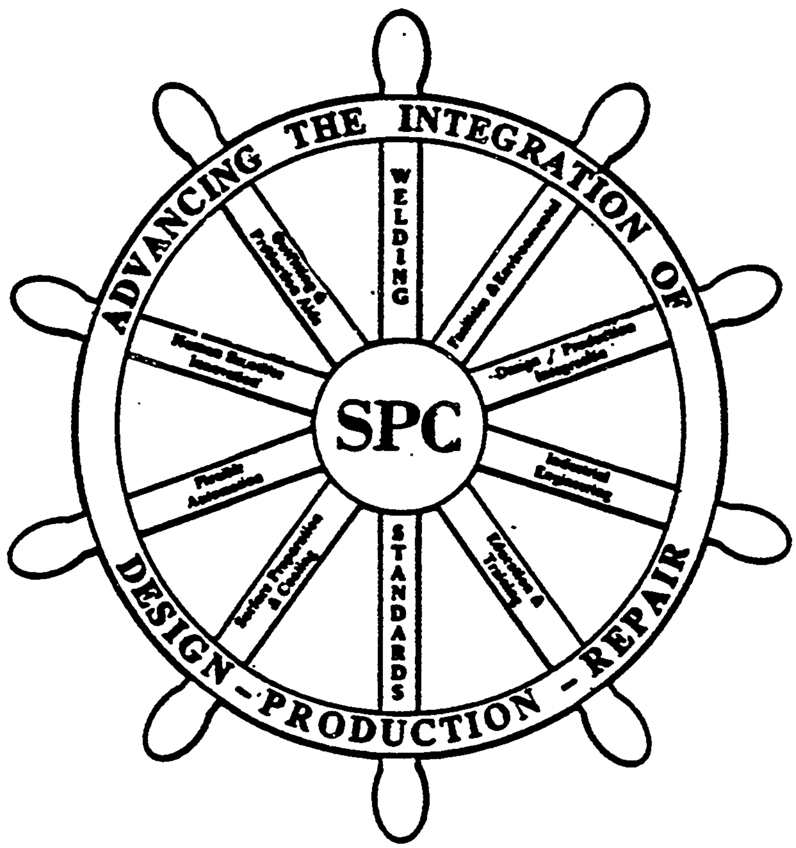
THE NATIONAL SHIPBUILDING RESEARCH PROGRAM
1989 SHIP PRODUCTION SYMPOSIUM

NSRP 0310



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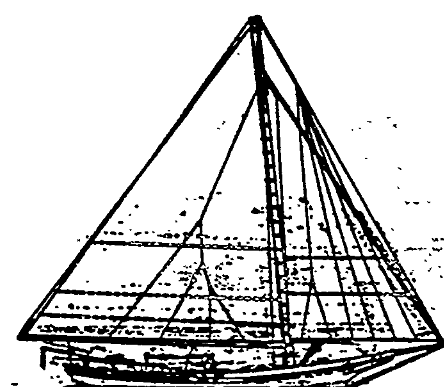
Arlington, Virginia



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THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS
601 Pavonia Avenue, Jersey City, NJ 07306
Paper presented at the NSRP 1989 Ship Production Symposium
Sheraton National Hotel, Arlington, Virginia, September 13 - 15, 1989

0310

No. 17

Significantly Reduced Shipbuilding Costs Through Constraint(s) Management

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Abstract:

Shipbuilding costs in the United States since 1973 have risen at a rate that is almost five times the rate of increase from 1939 to 1973. This is the same period when the numerous benefits of the National Shipbuilding Research Program (NSRP) were being realized by the U.S. Navy, shipyards and the industrial base industries. Clearly something far greater than a few sporadic improvements is now needed. Indeed, the only way to secure and improve one's competitive position today is by instituting a process of on-going improvement. Few would disagree that a process capable of generating an evolving, on-going improvement would be beneficial, but anybody who has tried to introduce any new process to an organization knows all to well the multitude of obstacles encountered. Experience shows that when these obstacles are closely examined, most will be found in the resistance of the people affected. This paper discusses the use of Constraint(s) Management as a process to overcome this resistance which then can lead to significant reductions in ship construction times and costs and possibly the revitalization of the U.S. Flag Merchant Marine.

INTRODUCTION

The Merchant Marine Act of 1970 initiated the National Shipbuilding Research Program (NSRP) to reduce shipbuilding costs and ship construction subsidies. This program has resulted in and continues to develop many productivity improvements in ship construction. There can be no doubt that the numerous improvements [1] made have resulted in reductions in production man-hours, construction times and should have reduced the overall cost of ships.

Figure 1 is a plot of the index of estimated shipbuilding costs for the year 1939 through 1988. It shows costs sharply rising after 1973. During the period 1939 through 1973 the index rose at the rate of about 10 points per year. During the period of sharpest increase (1973 to 1984) the general increase was 56 index points per year.

Figure 2 shows the percentage of LABOR INDEX and MATERIAL INDEX, which taken together, comprise the total estimated cost index. You can readily see that since 1952 the LABOR INDEX has dominated the total cost being about 60% in 1987 as compared to about 40% for the MATERIAL INDEX.

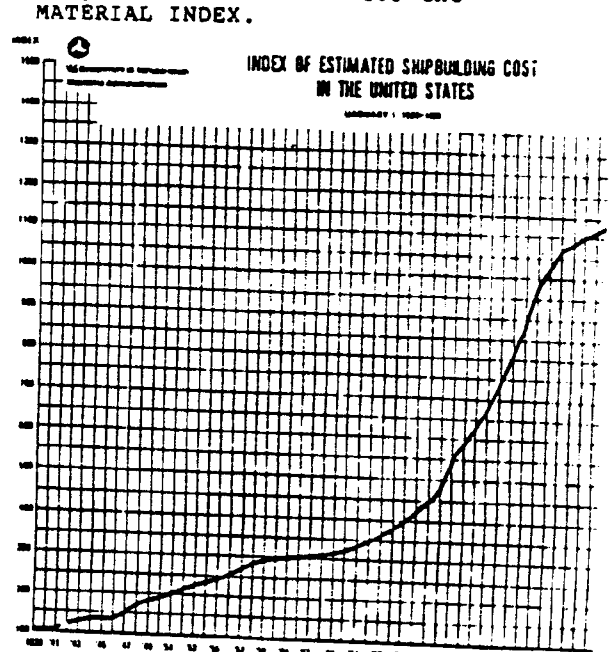


Figure 1

1. President Managing Change, Inc.
2. Numbers in brackets designate References at end of paper.

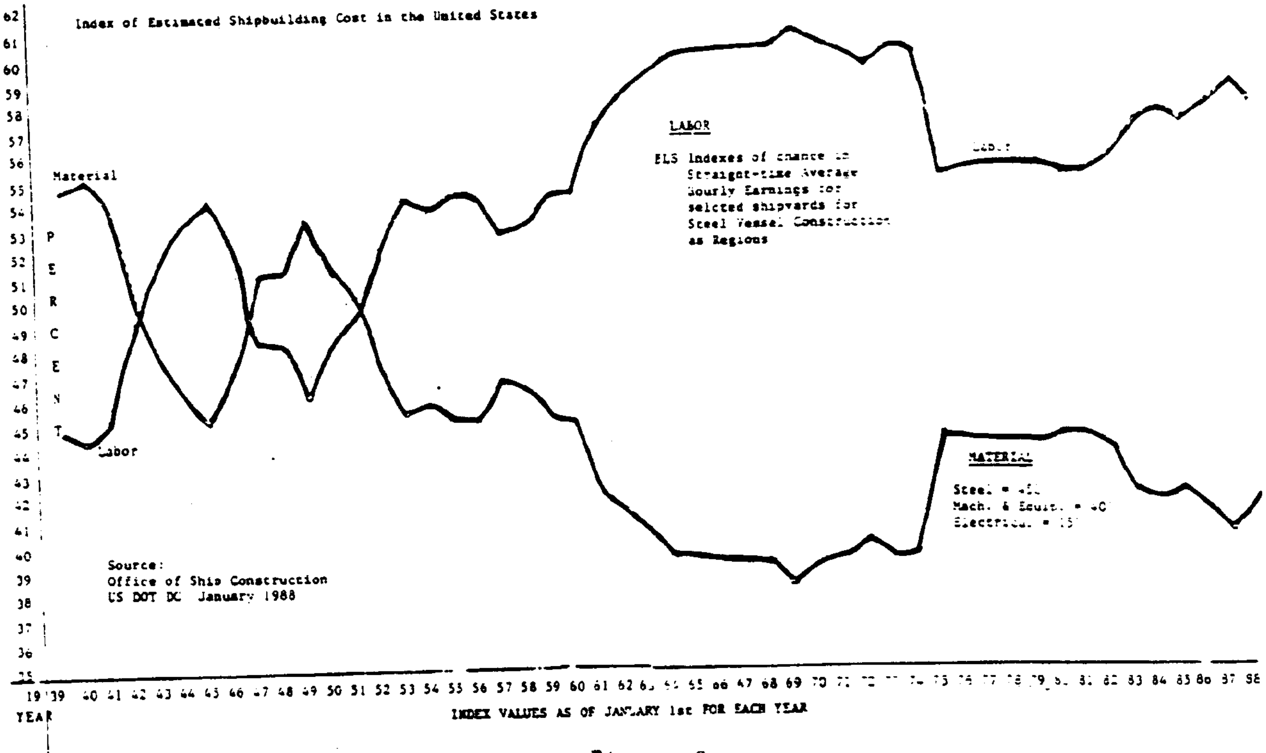


Figure 2

The improvements resulting from the NSRP are very difficult to estimate but one conclusion that can be drawn from Figure 2 is that there was only a net 2.5 index point reduction in labor costs during the period (1971 - 1988) when NSRP improvements were being implemented and that total shipbuilding cost increased at a rate five times the average of all previous years.

THE APPROACH

To quote from Reference [2]: "Clearly something far greater than a few sporadic improvements is now needed. Indeed, the only way to secure and improve one's competitive position today is by instituting a process of on-going improvement. In the absence of such a process the many improvements needed are certain to be sporadic and fragmented, wasting a great deal of energy, time and resources."

Part of this process of on-going improvement is the ability to question the assumptions behind what we have done and what we are about to do. The author began to question some of the conventional shipbuilding methods and procedures after reading Reference [3] in 1986. The continuing education provided to the author by the Avraham Y. Goldratt Institute (AGI) has resulted in challenging many more of our present conventional shipbuilding methods and practices.

Reference's [3] introduction states in part: "This book is an attempt to show that we can postulate a very small number of assumptions and utilize them to explain a very large spectrum of industrial phenomena. You the reader can judge whether or not the logic of the book's derivation from its assumptions to the phenomena we see daily in our plants is so flawless that you call it common sense. Incidentally, common sense is not so common and is the highest praise we give to a chain of logical conclusions. If you do, you basically have taken science from the very tower of academia and put it where it belongs, within the reach of every one of us and made it applicable to what we see around us."

Reference [2] examines some of the major changes that have taken place in all aspects of manufacturing in order to stay competitive. The area of logistical systems (flow of material) has seen the flowing major changes over the years:

- o 1950 - Order Point
- o 1965 - MRP
- o 1975 - Closed loop MRP
- o 1980 - MRP II
- o 1985 - Synchronized Manufacturing

Reference [2] states: "During the 40s, 50s, and into the 60s, we used manual "order point" techniques to control the ordering and flow of material in our plants and warehouses. This was our logistical system. About 1965, we tried for the first time to tap the power of the computer for this task through a technique called Materials Requirements Planning (MRP). Despite an investment estimated at $10 billion, we were not satisfied with the results. In 1975 we renamed it closed loop MRP, believing that feedback on the status of shop orders and purchase orders was the key to faster material flow. In 1980, it was MRP II, an effort to get the entire manufacturing organization- marketing, engineering, manufacturing and finance- singing off the same hymn sheet.

Each phase of our MRP journey involved large investments in computers, software and training in how we managed our businesses. It has been estimated that we have spent more than $30 billion, but even these enhancements and investments were not enough. MRP did not enable us to maintain leadership in the race for a competitive edge. The Japanese approach to the logistics of the shop floor, Just-in-Time/Kanban, proved superior to our efforts. Today some Western companies are attempting to emulate them. Meanwhile the Japanese and others are searching frantically for an even better system, called synchronized manufacturing, even though we have yet to define exactly what it is."

The author believes that most major U.S. shipyards are still in the late 1970's relative to implementation of a class A or B MRP II system. But wherever they are, shipyards need to improve their operations. Reference [4] states; "DOD contractors also should be continuously alert to advances in management control systems which will improve their internal operations."

Improvements can be realized by the management of change and the application of the Theory of Constraint (s), (TOC).

AGI as part of their educational improvement program has developed the matrix shown in Figure 3 to simplify top managements:

- o Tasks:
  Top management responsibilities
- o Qualifications:
  Needed to help solve these tasks
- o Techniques:
  That can be used to make the necessary changes

To establish a process of on going improvements AGI uses the Managing Change Matrix (MCM) shown in Figure 3 and the Theory of Constraints (TOC) listed on the next page.

MANAGING CHANGE MATRIX (MCM)

TASKS	QUALIFICATIONS	TECHNIQUES
The problems for top management:	The qualifications for a person to be able to answer the managerial problem:	The techniques that assist "Jonah"; (note 1)
1. What to change? Not everything has to be changed; most things are good enough as they are, or the gain that results from changing them barely justifies the efforts.	1. To be able to identify the core problems?	1. Effect-Cause-Effect This technique is used as a matter of course in Physics. Using this technique enables the Jonah to drive to the core problem.
2. To what to change? Many times when it is obvious that some particular process, or procedure, must be changed. It's far from obvious what to change to.	2. To be able to pinpoint a simple practical solution.	2. Evaporating Clouds If a big problem is considered to be a cloud, then this technique enable the Jonah not to solve a problem, but to cause the problem to disappear.
3. How to change?	3. To be able to induce the appropriate people to invent the correct solution.	3. Knowing how to cause a person to invent the right idea, by asking the right questions, at the right time, using his terminology.

A PERSON WHO HAS THESE THREE QUALIFICATIONS
IS CALLED A "JONAH™"
(See Note 1)

1: Experience has proven that the top man of a company MUST be a Jonah but not necessarily a teaching Jonah.

Figure 3

THEORY OF CONSTRAINTS:

Step 1: Identify the system's constraint (s).
Step 2: Decide how to exploit the system's constraint (s).
Step 3: Subordinate everything else to the decisions made in Step 2.
Step 4: Elevate the system's constraint (s).
Step 5: If a constraint is broken in Step 4, go back to Step 1.

But don't allow inertia to become the system's primary constraint.

However, When striving for improvements we have to remember that:

1. Any improvement is a change! We cannot improve something without changing it.
2. Any change is perceived, by most people, as a threat to security.
3. Any threat to security gives rise to emotional resistance.

Therefore, there is a need for a new type of education which gives rise to the emotion that strives for a change - the emotion of the inventor. This is the old Socratic approach.

APPLICATION OF MCM AND TOC

Before discussing the application of MCM and TOC to the shipbuilding industry let's look at the inherent conflict that is present in any organization - the "Pyramid Structure", Reference [5] discusses this conflict in detail and states the following conclusion: "... the uniformity of the management method used by all organizations throughout time, stems from the basic ability of individuals to directly handle only a relatively few people compared to the number of people in the organization. This means that organizations are using the hierarchical pyramid of management not because it is the best method but because it is probably the only workable method.

Does it mean that the hierarchical pyramid is good? Not at all. It just means that we cannot conclude anything about the pyramid's effectiveness just from the fact that it is so widely used. There simply are no other apparent alternatives. It also does not mean that substantial improvements are not possible. It only means that the most promising places to look for improvements are within the framework of a hierarchical pyramid and not outside it. The first place to look for a significant improvement is to find the biggest flaw in this method. Only by identifying flaws will we be able to devise improved ways. The bigger and more fundamental the flaw the greater the possibility of a substantial improvement."

One reading the above and the other discussions in Reference [5] is faced with a confusing and difficult situation. How do you develop a satisfactory solution to the inherent conflict of the hierarchical pyramid?

Let's now try approaching this situation using the "Evaporating Clouds" technique described in Reference [6].

"State precisely a problem and you are half-way toward solving it".

"State precisely a problem... translates to the absolute need for presenting the problem as a conflict between at least two (2) requirements."

In schematic form our problem will look like Figure 4 below:

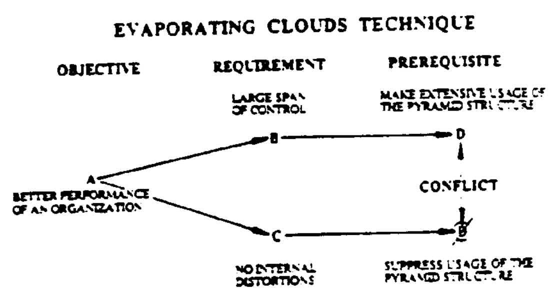


Figure 4

"A very different and much more promising avenue is opened when you realize that there is only one true underlying assumption behind each of the arrows in our diagram, Figure 4. These assumptions which we accept too often as "facts of life" are in many cases either erroneous or can be turned into irrelevant assumption for our particular case.

If an assumption can be shown to be invalid its corresponding arrow will no longer exist.

Eliminate even one arrow (it does not matter which one) from our diagram and the conflict simply vanishes. The problem is not solved, it evaporates. Whenever we are successful in addressing the problem in this way the objective is not compromised at all. In most cases eliminating an arrow leads us to a new perception of the situation. This new perception significantly increases our ability to satisfy the objective over and above what we previously perceive possible.

We call such a solution "second degree solution". All technical and scientific break throughs belong to this family of solutions. But these break throughs are sporadic and all too rare. Our challenge is to make them routine and common place."

SOLUTIONS

Reference [3] shows that "we can postulate a very small number of assumptions and utilize them to explain a very large spectrum of industrial phenomena."

The conventional way we (the USA) have confronted the problems of the Merchant Marine including shipbuilding and related industries has been to reduce the conflict by relaxing the requirements. The conventional way to search for an "optimum" solution is a constant on-going one.

It should be emphasized that this "optimum" solution we have accepted in the past is really nothing but another name for: "TOLERABLE COMPROMISE"

The author believes that these "Tolerable Compromises have led to the decline of the U.S. Flag Merchant Marine, the shipbuilding industry and related industries.

FINDING SOLUTIONS

How can we systematically find simple solutions to core problems?

Surprisingly it's not too difficult. What is really required is to refuse to take the seemingly easy way out and compromise between the requirements. A better way is to try and verbalize the assumptions underlying each of the arrows in the diagram. In order to force these assumptions to the surface, we must make extensive use of the question WHY? We must ask WHY? with the innocence of a small child otherwise the most "vulnerable" assumptions, those that we unquestioningly accept as fact of life, will not surface. Once the assumptions are verbalized, we must not hesitate to challenge them.

Unfortunately, the U.S. Flag Merchant Marine, manufacturing industries including shipbuilding and the marine equipment suppliers are losing the competitive race because they are not questioning the conventional way they are operating their businesses. Reference [3] elaborates in story fashion why the "Conventional Rules" are no longer valid and that if "Management" does not implement changes that are in accordance with References [2] "Global Rules" there is very little chance to be competitive.

Figure 5 lists the nine (9) "Conventional Rules", Figure 6 lists the nine (9) "Global Rules" which should be used as the basis for future actions. These "Global Rules" should not be considered as "Rules" that are unquestioningly accepted because although valid when Reference [2] was written they are no longer 100 % valid.

A good example is Rule 1: The conventional rule which has been universally used for many years is:

"Balance capacity, then try to maintain flow. Reference [3] supplies a good question and answer relative to "Conventional Rule 1." "Why do you think it is that nobody after all this time and effort has ever succeeded in running a balanced plant?" "... The real reason is that the closer you come to a balanced plant, the closer you are to bankruptcy."

WHAT RULES DRIVE YOUR BUSINESS?

CONVENTIONAL RULES

1. Balance capacity, then try to maintain flow.

2. Level of utilization of any worker is determined by its own potential.

3. Utilization and activation of workers are the same.

4. An hour lost at a bottleneck is just an hour lost at that resource.

5. An hour saved at a non-bottleneck is an hour saved at that resource.

6. Bottlenecks temporarily limit throughput but have little impact on inventories.

7. Splitting and overlapping of batches should be discouraged.

8. The process batch should be constant both in time and along its route.

9. Schedules should be determined by sequentially:
   - o Predetermining the batch size.
   - o Calculating lead time.
   - o Assigning priorities, setting schedules according to lead time.
   - o Adjusting the schedules according to apparent capacity constraints by repeating the above 3 steps.

MOTTO

The only way to reach a global optimum is by insuring local optimums.

Figure 5

WHAT RULES DRIVE YOUR BUSINESS?

GLOBAL RULES

1. Balance flow not capacity.

2. The level of utilization of a non- bottleneck is not determined by its own potential but by some other constraint in the system.

3. Utilization and activation of a resource are not synonymous.

4. An hour lost at a bottleneck is an hour lost for the total system.

5. An hour saved at a non-bottleneck is just a mirage.

6. Bottlenecks govern both throughput and inventories.

7. The transfer batch may not and many times should not be equal to the process batch.

8. The process batch should be variable not fixed.

9. Schedules should be established by looking at all of the constraints simultaneously. Lead times are the result of a schedule and cannot be predeterminied.

MOTTO

The sum of the local optimums is not equal to the global optimum.

Figure 6

Global Rule 1 states: "Balance flow not capacity" this rule provides a much better course of action than the conventional rule but requires a new definition to be more effective. Step 2 of the TOC says: "... exploit the system's constraint (s)." AGI's Drum-Rope-Buffer (DRB) technique provides for a buffer (inventory) before the constraint (s) to increase throughput and to exploit the constraint (s).

When you have a "buffer", which is inventory you can't have "flow" therefore Global Rule 1 is no longer valid. Dr. Goldratt provides us with an excellent new general Global Rule:

> "The Solutions of Today are the Diseases of Tomorrow."

CONTRACT PERFORMANCE

"Tell me how you measure me and I'll tell you how I'll behave. It's no wonder, with the growing recognition that current measurements are inappropriate, that most companies are struggling to find a better answer." The above quote is from Reference [7] which also discusses the following fundamental three (3) measurements that are recommended to be used for all for-profit-organizations.

"The first step in any attempt to build a formal system based on these three measurements is to define them precisely. The following definitions are used in References [2] and [3]:

(T) THROUGHPUT:
The rate at which the system generates money through sales.

(I) INVENTORY:
All the money the system invests in purchasing things the system intends to sell.

(OE) OPERATING EXPENSE:
All the money the system spends in turning Inventory into Throughput.

Reference [7] (21 Pages) and for a much more detailed exposure, Reference [8] (263 Pages) "Relevance Lost" The Rise and Fall of Management Accounting describes the "Fatal Flaws" of our present cost accounting systems.

Reference [7] also relates these measurements to the terms we presently use as measurements.

"As a matter of fact three measurements--Throughput, Inventory and Operating Expense--are perfectly capable of measuring the goal of making money, eliminating the need to use Net Profit (NP) and Return on Investment (ROI). Since we are accustomed to NP and ROI and have developed the intuition or "feel" for them (like we have a "feel for centimeters or inches), it would be counterproductive not to continue to use them, especially when the conversion between T,I,OE, and NP, ROI is so straightforward.

Net profit is just Throughput minus Operating Expense:

$$NP=T-OE \quad [1]$$

Return-On-Investment is just Throughput minus Operating Expense divided by Inventory:

$$ROI=(T-OE)/I \quad [2]$$

It is worthwhile to notice that we are currently using as measurements other combinations of T,I,OE. For example one of the most used non-financial measurements is inventory turns. Inventory turns is expressed readily by the ratio between Throughput and Inventory. Likewise the ratio between Throughput and Operating Expense is nothing but our old friend "Productivity."

$$\text{Inventory Turns} = \frac{T}{I} \quad [3]$$

$$\text{Productivity} = \frac{T}{OE} \quad [4]$$

The above clearly shows the conflict between a system that truly measures net profit (NP) and return on investment (ROI) to the systems that are presently being used in most shipyards. These are the same systems that are required by the USN (Reference [4]).

Item 9 of Figures 5 and 6 indicates the major differences between the "Conventional Rules" schedules and the "Global Rules" schedules. The "Conventional Rules" method of scheduling is being used to varying degrees in all U.S. shipyards that the author has visited.

The logic used in References [2] and [3] and the application of the deductive process taught by AGI clearly show the conflict between all of the "Global Rules" that apply to scheduling to the systems that are presently being used in most shipyards. Many of these systems are approved by the USN as meeting the "Schedule Control" objectives of Reference [4].

A major conflict results from using the Cost/Schedule Control Systems Criteria (C/SCSC) required by contract and the conventional planning and scheduling methods. The use of C/SCSC and conventional methods have a significant negative effect on the profitability of the shipyards.

References [2], [3], [5], [6], [7] and [8] provide sufficient evidence to prove that present cost accounting methods of measurements below the top level are "Fatally Flawed" therefore the author will use the measurements defined above in this paper.

PLANNING AND SCHEDULING

The basic "Flaw" in most shipyards planning and scheduling methods is that they are not using the Theory of Constraints (TOC) to establish their lead times for their many schedules at all levels. The present method (conventional) has resulted in a tremendous build up of inventories. The following example illustrates why constraint scheduling is necessary:

Let's assume that one production process has ten (10) dependent events (either machines or assembly) before an item is considered complete. Only one (1) of these events is determined to be a constraint. This constraint is the last event in the process and has only 80% the capacity of the other nine. Each work authorization (WA) has a schedule start and complete date of one week (5 days, 1 shift or 40 hours) and a budget for the work required to be performed and charged to that WA.

Material is released in sufficient time for the WA's to be completed on time, assuming good labor performance. The number of WA's scheduled for the process in one week total forty (40) and are equal to 100% capacity of the nine (9) non-constraints. Each Work Order has equal physical progress value when completed.

The following will be evident by the end of a one (1) week period:

Total WA's 100% complete	32	80%
Total Delinquent WA's	8	20%
Total WA's still in process	8	20%
Total WA's increase in inventory	8	20%
Labor Performance to Budget		100%
Physical Progress		80%

The above indicates everybody is working at 100% efficiency but that production is 20% delinquent to schedule and has only completed 80% of the physical progress required. In addition work-in-process (WIP) has increased 20% in a week. **WIP EQUATES TO INVESTMENT!**

Consider what the results would be if you had the same type of constraint in every shop, platten, erection position and at the waterfront. **YOU WOULD HAVE CHAOS!!!**

Fortunately there are very few constraints in a manufacturing process and usually after two (2) or three (3) rounds of applying the TOC concept the constraint becomes external.

THEORY OF CONSTRAINTS (TOC)

Let's apply the TOC to the above example. Step 1: Identify the system's constraint (s). The constraint in the system above is the last event which can be a piece of equipment (machine) or an assembly process. Step 2: Decide how to exploit the system's constraint. If the constraint is a machine the easiest way to exploit this constraint is to ensure that is is operating at all times and producing a product that is to be used (sold) in the very near future. A machine that is working on spare parts, defective parts, or parts that are scheduled later is not being exploited.

To break the above constraint the machine has to made to increase its capacity by 20% to meet the schedule (throughput) requirements. This can easily be accomplished in many ways, such as overtime, working through lunch and/or other scheduled breaks, multi-shift scheduling (most shipyards schedule their production work on a one shift, five (5) days a week basis) etc. If the constraint is an assembly operation then increased manning is the usual corrective action. Step 3: Subordinate everything else to the decisions made in Step 2. This step is not required if the decisions made in Step 2 resulted in increasing the capacity of the constraint (last event) 20%, as all ten events are now meeting 100% of the scheduled requirements. However, if the decision in Step 2 was to work the constraint on two (2) shifts instead of one then you are faced with the following situation: The constraint's capacity is now (80% + 80% =) 60% greater than the other nine (9) events which are still scheduled on a one shift basis. Your actions have resulted in meeting schedule and physical progress requirements and eliminating the 20% build up of work-in-process (inventory). Not bad-but let's look at the profit potential that is now available to us. We only have to increase the capacity of the other nine (9) events by 60% percent each to equal the constraint's capacity. This results in an increase in net profit of 129%.

A summary of net profit and productivity using the earlier measurement definitions and equations [1] and [4] for the three (3) scenarios discussed above is shown in Table I.

<u>ASSUMPTIONS</u>:

T = WA Value = $100 each x 40 = Total Scheduled Throughput of $4000

OE = $9 per machine hour x 10x40 = Operating Expense of $3600

<u>Schedule Requirements</u>

(T) Throughput $100 x 40 = $4000

(OE) Operating Expense $9x10x40 = $3600

<u>Net Profit</u> = NP = T - OE

NP = $4000 - 3600 = $ 400

<u>Productivity</u> = $P = \frac{T}{OE}$

$P = 1.11 = \frac{\$4000}{\$3600}$

<u>Actual Performance</u>

T = $100 x 32 = $3200

OE = $9x10x40 = $3600

NP = $3200-$3600 = $-400 Loss

$P = .89 = \frac{\$3200}{\$3600}$

Net Profit Variance from Schedule = $800

Potential

T = $100x40x160% = $6400

OE = $9x9x40x160% = $5184
OE = $9x1x40x200% = $ 720
Total OE $5884

NP = $6400 -$5884 = $ 516

P = 1.09 = $6400 / $5884

Net Profit Variance:
from Schedule = $ 116
from Actual = $ 916

TABLE I

Step 4: Elevate the system's constraint. In the above scenario this step is not necessary. This step is required when you have exploited the constraint to achieve its' full capacity, then you look for ways to increase (elevate) the constraint's capacity such as sub-contracting, offloading of work to less efficient machines etc. Step 5: When the constraint is broken go back to Step 1: But most importantly don't allow inertia to become the system's primary constraint. Inertia really means reverting back to the "Conventional Rules" and not using the "Global Rules" and the TOC.

INVENTORY

Most shipyards will experience an increase in their year end total inventory value. This increase is inevitable since it is caused by using the "Conventional Rules" such as the methods of scheduling and batching.

Reference [2] examines in detail the question "Who is Right - Our Financial System or the Japanese? Our Financial System looks at inventory as an ASSET. The Japanese look at inventory as a LIABILITY. The AGI educational methods prove to you that inventory is an asset only when it protects your Throughput (Sales).

Reference [2] state "The key to reduced inventory is: Synchronized Manufacturing.

But what do we mean by this phrase? "Reference [2] then defines this phrase and then state "first step toward synchronized manufacturing is to identify the constraints."

The number one constraint (core problem) preventing commercial ship construction in U.S. shipyards is the acquisition cost of U.S. build ships.

Let us now try approaching this problem using the same "Evaporating Clouds" technique.

In schematic form our problem will look like Figure (7) below:

EVAPORATING CLOUDS TECHNIQUE

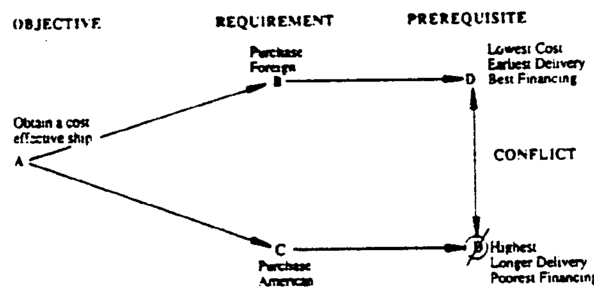


Figure 7

There is only one "second degree solution" that can be reached after reviewing Figure [7] above:

Purchase Foreign.

Ironically our "lawmakers" have made the same correct "second degree solution" in the past by allowing "build foreign windows" and hopefully common sense will soon prevail again and the same correct solution will be enacted into law.

It is generally recognized that the above correct solution did not remain as the "law of the land" because of the negative affect this law and other actions have had on two (2) major U.S. industries, i.e.: Shipbuilding and Marine Equipment suppliers (including steel and service companies).

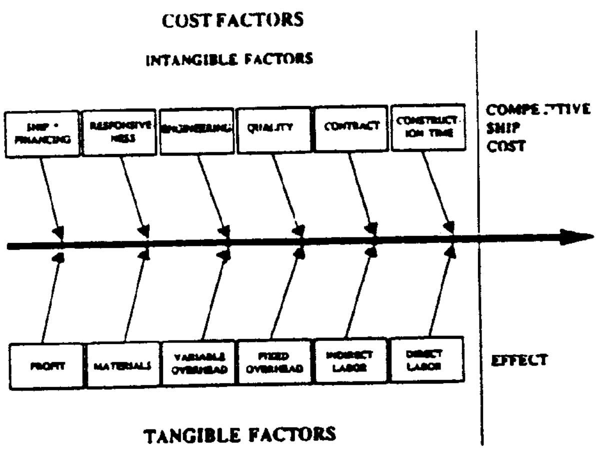
These two (2) industries probably would not object to a law that permits the Owner to "build foreign" if they had sufficient orders of ships to maintain the present number of shipyards in operation and their performance on these contracts resulted in acceptable profit margins.

The shipbuilding industry has to be educated on how to significantly reduce the costs and construction time of ships and how to make more money now and in the future by developing a process of on-going improvements.

The three ways to increase a companies Net Profit (NP) is by:
- o Increasing Throughput (Sales), (T)
- o Reducing Operating Expense (OE)
- o Reducing Inventory Expense (I)

The best way to increase net profit is to do all three things simultaneously.

Some intangible and tangible cost factors are shown in Figure 8. One core problem (Constraint) is the conventional way in which Owners contract for a ship. Reference [9] although written in 1975, still generally reflects the present relationships of the shipbuilding parties.



DISPERSION ANALYSIS CAUSE AND EFFECT DIAGRAM

* = Ship Owner Responsibility

Figure 8

A viable alternative for obtaining the best quality ship at lowest cost and as quickly as possible with minimum risks is to have the Owner enter into two (2) separate contracts.

The following describes how this alternative would be implemented:

A. Pre-Ship Construction Contract
B. Ship Construction Contract.

The Owner places a Pre-Ship Construction Contract with a Design Agent and a Shipyard that he selects from several available in each area that meet his requirements.

A. The contract requires that the ship be completely designed including all working drawings and shipyard production engineering requirements.

B. All purchase orders are written, competitive quotes are received, evaluated and vendors are selected. Long lead items that do not meet construction contract in yard required dates are placed as Owner Supplied Equipment (OSE).

C. The shipyard prepares a detailed cost estimate using all this heretofore unavailable information that they use to guess on in the preparation of their estimate and also using all the production engineering final information on which they also made assumptions for their estimate.

D. If the Owner is satisfied with the shipyards estimate he enters into a ship construction contract. If the Owner is not satisfied with the shipyards estimate as a basis for a fixed price contract he has the following possible alternatives:

1. Negotiate an acceptable fixed price contract with the shipyard.

2. Negotiate and agree on a fixed ceiling, target price and cost sharing type contract with the shipyard.

3. Request bids from an other shipyard using all data developed in the Pre-Construction Contract including production engineering data he already has paid for, except for the cost estimate prepared in C above which is shipyard proprietary information, and any production engineering data so determined to be proprietary as part of the Pre-Construction Contract.

The approach recommended above has the following significant advantages:

- o Greatly reduces the owner and shipbuilders risk.
- o Eliminates most unknowns.
- o Ship is designed for profitability.
- o Ship is designed for producibility.
- o Construction time can be shortened resulting in additional operating revenues.

- o Type of contract brings the parties closer together to obtain mutual benefits.

The approach recommended above with some modifications is also applicable to USN ship construction contracting.

Let us now consider some of the intangible cost factors and explore how MCM and TOC can be applied to them.

INTANGIBLE COST FACTORS

The following are the major intangible cost factors that affect obtaining a competitive ship:

- o Responsiveness
- o Engineering
- o Quality
- o Contract
- o Construction time
- o Ship Financing*

* Ship financing is primarily the responsibility of the commercial ship owner (USN). This subject will not be addressed in this paper.

Responsiveness

Reference [2] contains a very good discussion of this intangible cost factor. Responsiveness is composed of two parts:

1. Better due-date performance
2. Shorter quoted lead time.

A company can gain the competitive edge by having a higher percentage of on time deliveries than their competitors. "Due date performance differs from shorter quoted lead times, the second responsiveness avenue. This advantage gives us the ability to commit to an earlier delivery than our competitors. Every salesman has learned the significant advantage in offering the client fast deliveries."

Reference (2) develops a very convincing presentation to prove that the real solution to good responsiveness" is totally under the plants control - its level of work-in-process inventory."

Engineering

Engineering is listed as an intangible cost factor because of the non- measurable impact that results from the poor quality, poor schedule performance and poor responsiveness changes (USN and internal).

The author's experience was expressed as follows in Reference [10]. "The key to a successful shipbuilding contract is how well the Engineering department performs. If engineering can issue complete approved plans and material requisitions on schedule the first hurdle is passed. However many times Engineering is not allowed enough time in the schedule and the result is that preliminary plans or incomplete plans are released to the yard. Many yards make the mistake of working to these preliminary or incomplete plans in the hope that when the "clean" plan is issued they will have minimum rework.

Past experience has proved that this is not the case. The results of working to preliminary plans are:

- a) Production man-hours used for installation and then ripout results in no physical progress.
- b) Material costs have increased
- c) All paperwork had to be redone and reissued
- d) Work is more delinquent to schedule than if it was not performed
- e) Supervision and worker morale suffer.

With the present great need for trained shipyard workers the best course of action has to be <u>not to work</u> an area where the plans are not "clean" and for management to expedite resolution of problem areas."

Shipyards that are the follow-on-yard for USN work have additional problems if the lead yard is having difficulties in finalizing the design, engineering and procurement requirements for the lead ship.

The authors suggestion that the parties should enter into a Pre-Construction Contract would result in "Evaporating" most of the above problems.

Quality

The subject of this intangible cost factor has received an enormous amount of attention ever since the Japanese began winning the "competitive race". Those who have lived through the period of implementation and use of the USN's MIL-Q-9858A can tell of their many "trials and tribulations".

The author firmly believes that if each worker understands the importance of quality and how it will affect him and the company's profitability he will produce a "quality product". The old adage has been proven over and over:

YOU CAN'T INSPECT QUALITY INTO A PRODUCT!

However, to meet and interface with the USN requirements shipyards have had to establish large QA departments.

If you were to measure the QA departments contribution to net profit you would have to question its usefulness in many areas.

How can the QA department be productive and contribute to increased T or a reduction in I or OE expenses? The author's answer is that the QA department can be productive by managing (overseeing not doing) a Total Quality Assurance (TQA) system including using such techniques as Statistical Process Control (SPC) and others described by Dr. Deming and others. The Cause and Effect diagram approach used in this paper is described along with other useful techniques in Reference [11].

In today's competitive race shipyards must strive for "Zero Defects". The 1% defect rate thought to be an unreachable goal years ago is no longer acceptable. If every functional department that provided the material and information to production had a 1% defect rate it would be one of the major causes of shipyards problems.

As an example: if a ship was made up of a million parts, a 1% defect rate would represent 10,000 bad parts. If each department repeated this 1% defect the results may be as follows:

	# of Defects	Cumulative
Engineering	10,000	10,000
Purchasing	10,000	20,000
Vendor	10,000	30,000
Shipping	10,000	40,000
Inventory	10,000	50,000
Routing	10,000	60,000
etc, etc:	---	too much.

The above means that before the production people start building a ship they lack over 60,000 parts which will prevent them from completing the assigned WA's.

Contract

Present USN methods of contracting for ships are significantly different than those of the 1960's - 1970's. The major requirements that were added by the USN for various reasons were thought at the time to be valid and necessary. The author maintains that many of the assumptions behind these contract requirements would not today pass the "Evaporating Clouds" technique test.

It is not the purpose of this paper to discuss the "Pro's" and "Con's" of USN contracting methods except to point out the significant mutually beneficial financial benefits that can be realized if the non-productive contract clauses were deleted, revised or made optional.

Ship delivery date is an excellent example of one such contract requirement. The USN inflexibility in this area blocks many of the significant financial benefits that could result from earlier ship delivery dates.

Construction Time

The USN presently establishes by contract the delivery date of a vessel and working with the shipyard establishes mutually acceptable key events dates, which are used in planning and scheduling all the thousands of requirements. The author has assumed for the purpose of this discussion that the delivery date (D) has not been set and the shipyard has some leeway as to when they schedule start of fabrication (SF).

Construction time and other intangible cost factors affect each of the following elements that are part of the total price of a ship. The estimated percent of each of the following elements that will be used in this paper are as follows:

ELEMENT	EST. PERCENT	EST. BASE SHIP
Total Sales Price	100%	$100,000,000
Total Profits (Before Taxes)	10%	$ 10,000,000
Total Material	40%	$ 40,000,000
Total Overhead	30%	$ 30,000,000
Total Labor	20%	$ 20,000,000

Figure (9) shows a base ship key events schedule for a contract that requires delivery of the ship four years from contract award. Also shown are the key event schedules for an accelerated schedule resulting in ship delivery at the end of the second year and Alternative #1 that utilizes the pre-construction and construction type contracts discussed earlier. Alternative #2 is shown to indicate the key events for a ship built in one half the construction time period - 30 months (62.5%) of the base ship contract time.

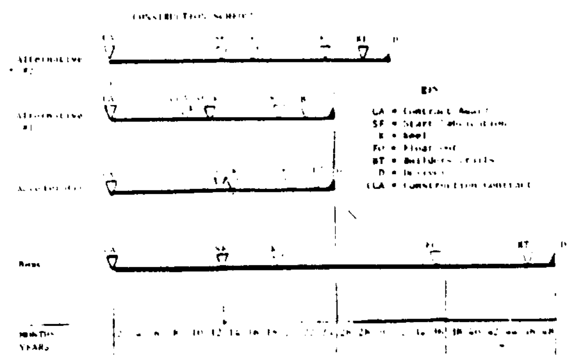


Figure 9

Figure (10) shows the estimated cost expenditures curves for each case. Except for Alternative #1 which is based on a different method of contracting all three cases expend ten percent of total cost in the first year.

Alternative #1 is shown in Figures (9) and (10) mainly to indicate the flexibility it offers the "Owners" (USN) and the shipbuilder in ship construction durations and more importantly in minimizing the great risk of not having complete engineering, including shipyard production engineering and firm prices on all materials items. By completing all this work prior to entering into a ship construction contract, the shipyard can significantly reduce the amount of "contingency". The potential for constructive change claims is also minimized.

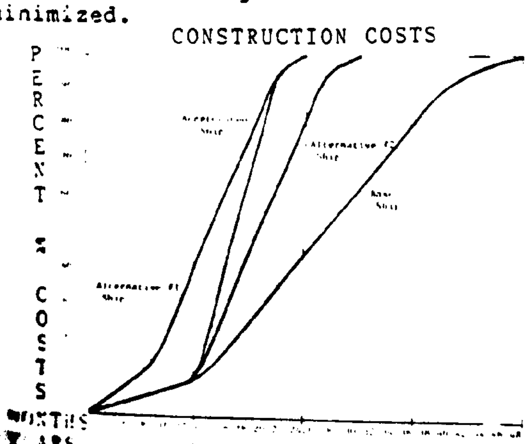


Figure 10

In today's conventional shipbuilding the base schedule is not representative of the actual time required to build a ship. The base schedule represents a major "stretch out" of the work from start of fabrication to builders trails. Start of fabrication is usually scheduled as early as possible consistent with engineering and material support so the shipyard can start construction resulting in increased progress payments.

The shipyard then "levels" their scheduled progress to fill the remaining time to delivery. The shipyard can't level the work in the last year of construction because there is not that much physical progress required to complete the ship as required in the first two years as shown in Figure (10). A comparison of physical progress requirements per year for the three cases is shown below:

	Base Ship	Accel.	Alt. #2
1st Year	10%	10%	10%
2nd Year	35%	90%	70%
3rd Year	35%		20%*
4th Year	20%		

* 6 Months

Construction time is an intangible cost factor that has the greatest impact on all of the tangible cost factors.

Step 2 of the MCM Figure (3) is to be able to pinpoint a simple practical solution.

Figure (8) listed the tangible and intangible cost factors that are the major contributors to the cost of building ships in the U.S.. The author has identified "construction time" as the single most important cost factor that results in U.S. shipbuilding being non-competitive.

Significant cost savings can result from reduced construction times. The use of MCM and TOC technology will also result in other major cost savings through productivity improvements. These productivity improvements are attained as a result of major reductions in work-in-process and are in both the labor and material areas.

Reference [10] discusses other methods such as superunits, increased pre-outfitting and packaging etc. that will also result in significant reductions in construction durations.

The above discussion and the authors experience has shown that reductions in construction times of the magnitude required by the Figures [9] and [10] schedules are attainable.

CONSTRUCTION TIME COST SAVINGS

The impact on net profit (before taxes) resulting from shortened construction times is shown in Table II. For ease of comparison the full base ship estimated cost is equally spread over the three year construction period instead of the four year contract period.

Base Ship 3 Yr Construction Period %			Base Ship 1 Year
100	$100,000,000	Total	$33,333,333
10	10,000,000	Profit	3,333,333
40	40,000,000	Material	13,333,333
30	30,000,000	Overhead	10,000,000
20	20,000,000	Labor	6,666,666

Table II indicates very substantial total savings of 23.5% and 32% of total ship costs for Alternative #2 and the Accelerated ship respectively resulting from shortened construction time. The shipyard would also benefit by increasing their yearly profits by 100% and 200% respectively.

Table II below clearly shows that the single most important cost savings resulting from reductions in construction time is Overhead costs. An average of sixty three (63) percent of the cost savings for both cases is in Overhead. Twenty five (25) percent of the cost savings for both cases is in the material area and results from savings in inventory carrying costs. These carrying costs, which are estimated at 20% per year, are paid for by either the shipyard or the Owner (USN). Direct labor savings only account for an average twelve (12) percent of the total savings in both cases.

These direct labor savings result from services that are no longer required due to reduced construction times. Examples of some time related services are Supervision, inspection, rigging, cleaning etc. Direct labor charges for these services range between 20 and 30 percent of the everyday total direct labor. Table II calculations are based on a 25% estimate.

CONSTRUCTION TIME SAVINGS SUMMARY

Alternate #2 1 1/2 Years Construction Period (50% of Base Ship)

Area	Savings	% of Savings	Reason
Overhead	$15,000,000	64	1 1 2 Year Less Time
Labor	2,500,000	11	25% Time Related *OE ($10,000,000 x 25%)
Material	6,000,000	25	50% of Base Ship Carrying Cost (20%). ($40,000,000 x 50% x 20% x 3 Years = $12,000,000
Total Savings	$23,500,000	100	
Increased Profits	+$3,333,333		100% Increased Profits in same time period

Accelerated Ship 1 Year Construction Period (66.7% of Base Ship)

Area	Savings	% of Savings	Reason
Overhead	$20,000,000	62	2 Years Less Time
Labor	4,166,667	13	25% Time Related *OE
Material	8,000,000	25	66.7% of Base Ship Carrying Cost (20%)
Total Savings	$32,166,167	100	
Increased Profits	+$6,666,667		200% Increased Profits in same time period

* OE = Operating Expenses

TABLE II

In addition to the above the use of MCM and TOC technology will result in other major cost savings through productivity improvements. These productivity improvements are attained as a result of increased throughput, reduced operating expenses and greatly reduced inventory (work-in-process) and are in both the labor and material areas.

If we assume a 30% improvement in the labor area and a 20% improvement in the material area the additional saving over those shown in Table II for the Accelerated ship and Alternative #2 would be as shown below:

Productivity	Accel. Ship	Alternative #2
Labor	$ 4,750,000	$ 5,250,000
Material	6,400,000	6,800,000
Total	$11,150,000	$12,050,000

Table III below indicates a new situation if you assume that the shipyard maintained their 10% profit on the ship contract and that the cost of the base ship is reduced as a result of the reduction in construction time and productivity improvements:

NEW BASE SHIP COST SUMMARY

Accelerated Ship

% of Base Ship		Ship Costs	% of Base Ship	% of New Total
40	Material	$25,600,000	64.0	49.4
20	Labor	11,083,333	55.4	21.4
30	Overhead	10,000,000.	33.3	19.2
10	*Profit	$ 5,187,037	155.6	10.0
New Ship Cost		$51,870,370		

Alternative #2

% of Base Ship		Ship Costs	% of Base Ship	% of New Total
40	Material	$27,200,000	68.0	45.0
20	Labor	12,250,000	61.3	20.0
30	Overhead	15,500,000	50.0	25.0
10	*Profit	$ 6,050,000	121.0	10.0
New Ship Cost		$61,000,000		

* Profit = 10% of New Ship Cost

TABLE III

The above indicates the magnitude of estimated savings resulting from reductions in construction time and productivity improvements in a shipyard.

As a result of these estimated savings, Material has now become a larger component of total ship costs and Overhead a lower percentage, while the Direct Labor percentage of cost has remained essentially the same. Profits have increased significantly in both cases. Material costs usually break down into the following three area:

- o Raw Material
- o Equipment
- o Consumables

These three areas have one thing in common; they all result from a manufacturing process. Therefore, the technology that was applied to the shipyard resulting in the above cost savings is directly applicable in the material area to the material supplier manufacturing process, which should result in more than the 20% productivity improvements used in earlier calculations.

However, there is another major obstacle that must be addressed relative to the USN and that is the "Conventional Inertia" of the Government bureaucracy. The author calls this obstacle: BLOCKAGE!!!

Blockage

Webster defines Blockage: An act or instance of obstructing.

The act of Blockage can be intentional or unintentional. The intentional Blockage is easier to deal with because you generally know what the obstruction is and why it has been established. A few specific examples of Blockage that relate to the shipbuilding industry's present situation are:

- o Cost Accounting Procedures
- o Planning & Production Control
- o Purchasing & Inventory Policies
- o USN Ship Construction Contracts
- o Reference [4] DOD Inst. 7000.2

Unintentional Blockage is very difficult to remove because you must overcome the conventional inertia that has been established in the mind of every individual since birth.

If we assume that the shipyards have implemented MCM and TOC and have educated all levels of the organization on how they can contribute to the "Global Optimum" of "how to make more money now and in the future", the following significant positive changes will be evident:

- o Increased Throughput
- o Reduced Operating Expenses
- o Reduced Inventory Expenses
- o Increased Net Profit
- o Improved Return on Investment
- o Improved Cash Flow
- o Increased Inventory Turns
- o Increased Productivity

These improvements really mean that the shipyard has implemented a process of on-going improvements. However, early in this process the shipyard will recognize a tremendous reduction of work-in-process and the fact that the shipyard has excess capacity. Management also recognizes that through the implementation of a process of on-going improvements they have made their human resources much more valuable.

The obvious solution to this situation is to increase sales; because, if they do not increase sales, they either have to slow down production or reduce their work-force or a combination of these two unacceptable alternatives.

In today's business environment, the likelihood of new ship construction contracts (Commercial or Government) is slim to none. So the shipyards will be in a "Catch 22" situation due to the fact that their present USN ship construction contracts require delivery dates that will require a tremendous slow down in production and the resulting reduction in human resources.

The author believes that since there are only two primary "players" in a ship construction contract and both have been identified as the core problem (constraint) to competitive ship construction or in the USN case "more bang for the buck", that one of the best approaches to take is to prove that what is being recommended will make both parties:

WINNERS!

The shipyards will become a WINNER just by implementing the recommendations made in this paper. They will greatly increase their profits if the USN participates and eliminates the "Blockage" to earlier ship deliveries.

In accordance with the MCM we have to:

1. Identify The Core Problem
2. Find a Simple Practical Solution
3. Induce The Appropriate People To Invent the Correct Solution

CONCLUSIONS

The author in this paper has discussed how the Theory of Constraints and other existing technology can be applied to reduce the cost of building commercial and USN ships. This same technology can be applied by all elements associated with the U.S. Maritime Industry to make it more competitive in the world marketplace.

The revitalization of the U.S. Flag Merchant Marine can be accomplished by those responsible individuals within the industry if they use the resources that are readily available. One vital resource we have not used to its full potential is our God given brains. Americans have been complacent for so long and the old conventional ways have been so firmly established as our way of life that we seldom challenge the "Tolerable Compromises" that are being made every day.

This nation's problems are immediate and require economical solutions. The Maritime Industry must look to itself! To quote from a speech made by Joseph Farrell President of the America Waterways Operators Inc. (AWO) at the 1984 Propeller Club's annual meeting: "To paraphrase Jack Kennedy, ask not what your government can do for you. Be sure your government knows who you are and what you do for it."

How can we quickly increase the U.S. Flag portion of U.S. foreign trade and at the same time increase the profitability of all the elements that make up the Maritime Industry, meet military sea-lift requirements and also reduce trade deficits and contribute to reducing our budget deficit? The answer is: Do What is Right! which is the same as the "Global Objective" for all manufacturing and service companies i.e.: "To Make More Money Now and In The Future". The author maintains that by using TOC, MCM and other techniques discussed in this paper this "Goal" can be attained. Consider the following:

- Only by increasing cargo tonnage will we increase the need for operating U.S. Flag ships.
- Only by being more competitive will we obtain increased cargo tonnage.
- Only by purchasing a ship from a foreign source at this time can we be more competitive.
- Increases in the number of U.S. Flag ships, will result in employing more US seafarers who will operate and maintain the ships in revenue producing operations. These ships are ready to respond with a trained crew, when needed by this nation.
- Reducing the cost of US shipbuilding will possibly make the "Build and Charter" and other programs economically justifiable resulting in increased US shipbuilding and marine suppliers orders.
- Reduced construction time on existing USN shipbuilding contracts can increase profits reduce overruns and/or result in additional orders due to cost savings sharing.

The above is only a partial listing of the potential benefits that can result from a united industry program of:

DOING WHAT IS RIGHT!

Acknowledgments

The author would like to acknowledge with thanks the education, support and encouragement provided by Dr. Eliyahu M. Goldratt, Educator and Mr. Robert E. Fox, President of the Avraham Y. Goldratt Institute in preparing this paper. The author also would like to thank Mr. Bob Schaffran and Mr. Oren Stephens for their great help in commenting on, reorganizing and condensing this papers contents. However the views and the conclusions expressed therein are solely his and do not necessarily reflect those of the Goldratt Institute or others.

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